(12) UK Patent Application (19) GB (11) 2 253 770 (13) A

(43) Date of A publication 16.09.1992

(21) Application No 9100774.0

(22) Date of filing 15.01.1991

(71) Applicants
Rogers Cantel Inc
(Incorporated in Canada)
10 York Mills Road, North York, Ontario, M2P 2C9, Canada

Rogers Cable T.V. Limited
(Incorporated in Canada)
853 York Mills Road, Don Mills, Ontario, M3E 1Y2, Canada

(72) Inventors
Nicholas Francis Hamilton-Piercy
Donald Graham Monteith
Roger David Keay
George Maynard Hart
Meng Yee
Peter Oldfield
Philip Leighton
Edward O'Leary

(51) INT CL[5]
H04H 1/08, H04M 11/00, H04Q 7/04

(52) UK CL (Edition K)
H4R RCC
U1S S2204 S2213

(56) Documents cited
US 4757496 A US 4644526 A

(58) Field of search
UK CL (Edition K) H4R RCC RCSC RCX
INT CL[5] H04H
Online databases : WPI, CLAIMS, INSPEC

(74) Agent and/or Address for Service
J Y & G W Johnson
Furnival House, 14-18 High Holborn, London, WC1V 6DE, United Kingdom

(54) Multichannel radiotelephony system using bidirectional cable T.V. network

(57) Two way cordless communications uses multichannel transceivers portable within a coverage area comprising cells, each associated with a base station and antennas, such as to permit channel frequency reuse in cells within the coverage area. For at least part of the coverage area, the locations of the antennas within the cells and the locations of the base stations are independently mapped, the antennas being associated with active antenna systems and the active antenna systems being connnected to the base stations utilizing broadband transmission by means of a fixed bidirectional cable television network. The network is connected to the base stations and the antenna systems through interfaces incorporating frequency translation so that available frequency bands in the cable television network, which will normally be shared with other services, may be utilised. Plural base stations may be co-located. The radio link to the transceivers may be FDM or TDM, but communication over the network will normally be frequency multiplexed, using separate bands for transmission and reception.

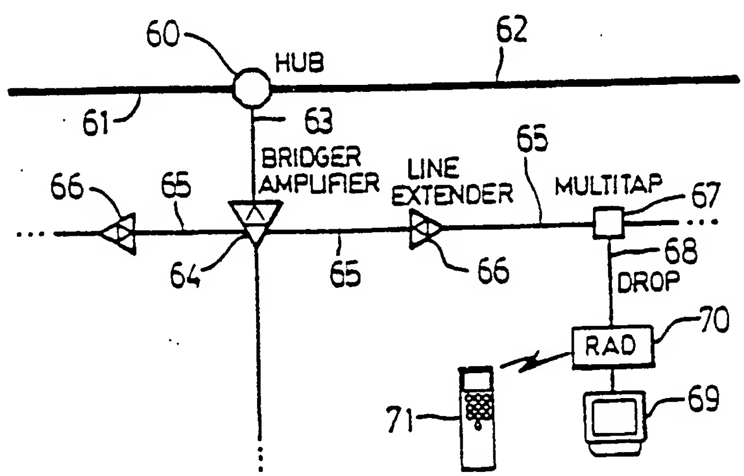

FIG. 1

At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

The print reflects an assignment of the application under the provisions of Section 30 of the Patents Act 1977.

GB 2 253 770 A

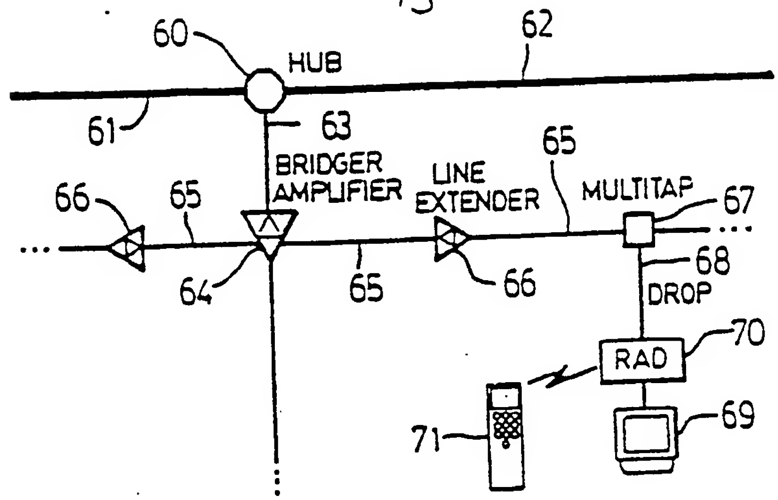
60
HUB
62
61
63
BRIDGER AMPLIFIER
LINE EXTENDER
65
MULTITAP
67
66
65
64
65
66
68
DROP
RAD
70
71
69

FIG. 1

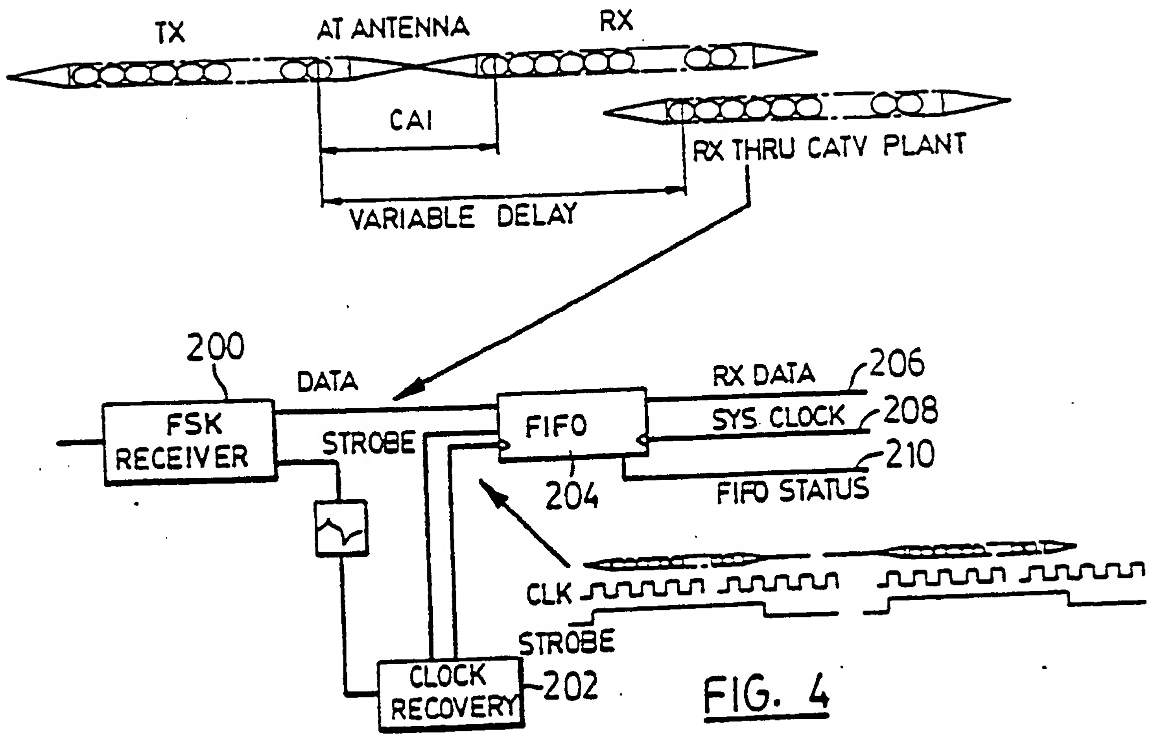
TX
AT ANTENNA
RX
CAI
RX THRU CATV PLANT
VARIABLE DELAY
200
DATA
RX DATA
206
FSK RECEIVER
STROBE
FIFO
SYS. CLOCK
208
210
204
FIFO STATUS
CLK
STROBE
CLOCK RECOVERY
202

FIG. 4

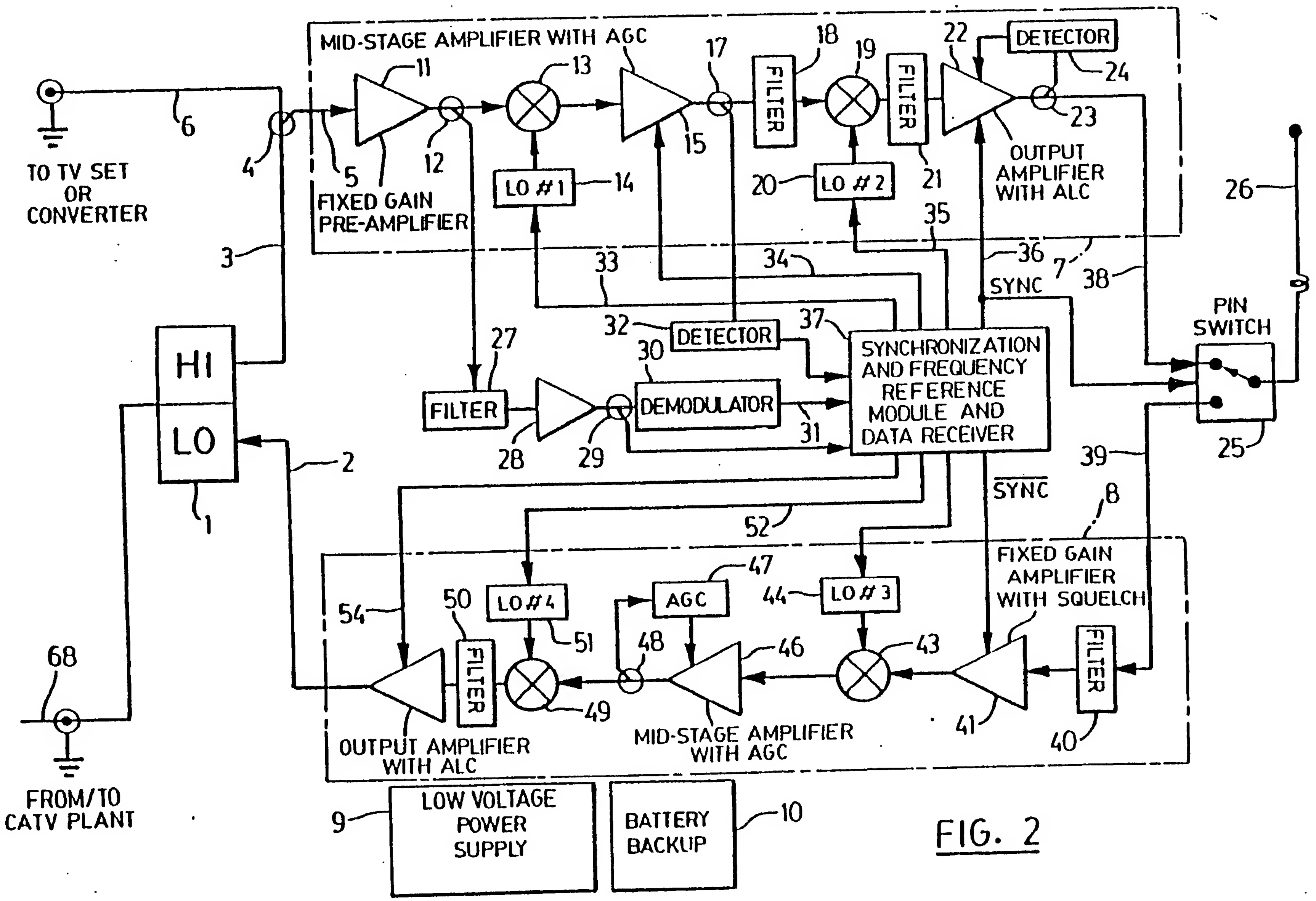
MID-STAGE AMPLIFIER WITH AGC
FIXED GAIN PRE-AMPLIFIER
OUTPUT AMPLIFIER WITH ALC
DETECTOR
FILTER
FILTER
LO #1
LO #2
TO TV SET OR CONVERTER
HI
LO
FROM/TO CATV PLANT
FILTER
DETECTOR
DEMODULATOR
SYNCHRONIZATION AND FREQUENCY REFERENCE MODULE AND DATA RECEIVER
SYNC
SYNC
PIN SWITCH
FIXED GAIN AMPLIFIER WITH SQUELCH
FILTER
LO #3
LO #4
AGC
FILTER
MID-STAGE AMPLIFIER WITH AGC
OUTPUT AMPLIFIER WITH ALC
LOW VOLTAGE POWER SUPPLY
BATTERY BACKUP
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
43
44
46
47
48
49
50
51
52
54
68

FIG. 2

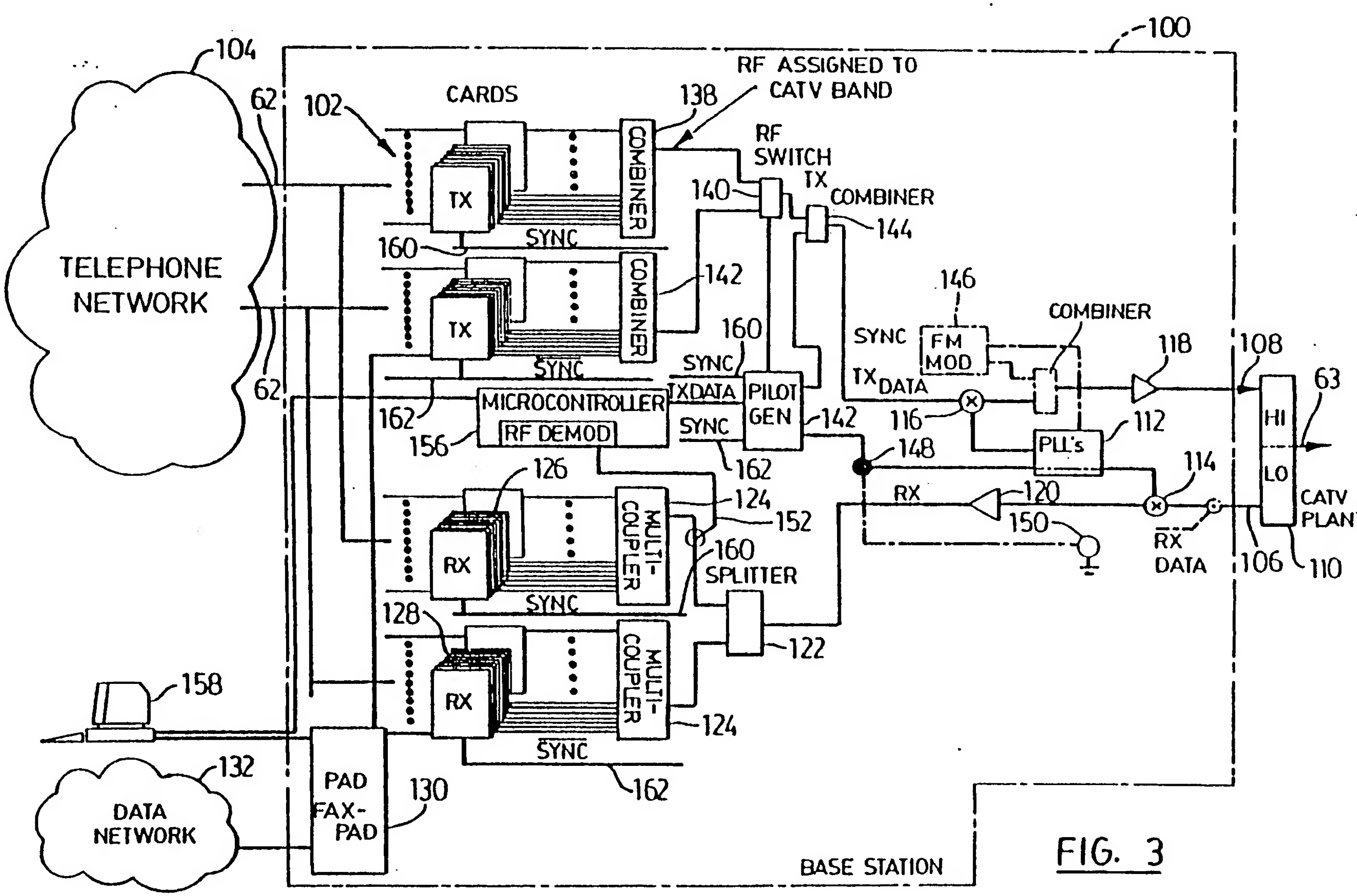
100
104
TELEPHONE
NETWORK
62
62
102
CARDS
TX
TX
RX
RX
SYNC
SYNC
SYNC
SYNC
160
162
COMBINER
COMBINER
138
142
RF ASSIGNED TO
CATV BAND
RF
SWITCH
TX
COMBINER
140
144
160
SYNC
TXDATA
PILOT
GEN
142
SYNC
162
MICROCONTROLLER
RF DEMOD
156
162
126
124
152
160
MULTI-
COUPLER
MULTI-
COUPLER
SPLITTER
122
124
128
162
146
SYNC
FM
MOD
TX DATA
COMBINER
116
PLL's
112
118
148
RX
120
150
114
RX
DATA
108
HI
LO
63
CATV
PLANT
106
110
158
132
DATA
NETWORK
PAD
FAX-
PAD
130
BASE STATION

FIG. 3

RADIOTELEPHONY SYSTEM

This invention relates to the interface between a telephone network and portable wireless telephone units in a radiotelephony system and more particularly to equipment for the implementation of a personal communications service utilizing cable television facilities.

The development and commercial success of both cellular telephone systems, primarily for mobile use, and cordless telephones, for use in the vicinity of fixed locations within the public switched telephone network (PSTN), has given rise to considerable interest in the provision of tetherless personal communications using small portable handsets within a system which combines some of the personal mobility afforded by a cellular system with the lower cost and greater system capacity afforded by cordless telephones. Proposals for several systems have been published and some cases have been the subject of public trials. Such systems are commonly referred to as second generation cordless telephony (CT2), third generation cordless telephony (CT3), and generically as personal communications services (PCS). Further information on such systems may be found for example in the following publications:

"Personal Communications - A Report on CT2 & PCN Wireless Communications Systems" by Matthew Dosch, published 1990 by Telecom Publishing Group.

"Generic Framework Criteria for Universal Digital Portable Communications Systems (PCS)" published March 1990 by Bellcore.

"MPT 1375 Common Air Interface Specification" published by Department of Trade & Industry, London, England,

1989.

"Second generation cordless (CT2) telephony in the U.K.: telepoint services and the common air-interface" by Professor J.G. Gardiner, Electronics & Communication Engineering Journal, April 1990.

"CT2 Plus - A proposal for a Canadian Common Radio Interface Standard", Issue 2.0, December 1990, Bell-Northern Research.

"CT3 - Common Radio Interface Specification for Canadian Cordless Communications" December 19, 1990, Novatel Communications Ltd and Ericsson Communications Inc.

A common objective of the above PCS systems is the provision of wireless telephony via small portable handsets to individuals, either stationary or pedestrian. This wireless service is intended to be available at low cost to the general public and operate within and about the home, shops, schools, offices and institutions where telephone usage is most likely to be required. Wireless telephony is made possible by way of a portable radio handset carried on the person and a complementary radio base station connected to the public switched telephone network (PSTN) within operating range of the handset. This operating range is likely to be in the vicinity of 1000 feet or less, being primarily limited by the transmitter power available in a small portable handset, with the result that a very large number of base station locations is required to provide substantial area coverage.

The interconnecting of many spatially distributed radio base stations with the PSTN and the associated intelligence

required to locate mobile handsets has been termed a personal communication network (PCN). The construction and operation of a PCN will be required in order for PCS to be achieved. A large number of complex radio base stations need to be deployed over a substantial area to support adequate radio access for the general public to purchase the service. Each radio base station transforms, in a duplex manner, voice signals in a format suitable for transmission on twisted pair or fiber optic facilities, into radio frequency (RF) signals suitable for exchange with the portable handset.

In all cases, a complex signal multiplexing arrangement is used to conserve scarce RF spectrum, available allotments being in the vicinity of 1000 MHz. Radio base station equipment must include circuitry to properly multiplex and de-multiplex the RF signals exchanged with the portable handset.

In the case where more than one handset is expected to be in radio contact with a base station, the circuitry necessary for one duplex conversation or voice channel needs to be duplicated for each handset. The number of users who can access a particular radio base station will therefore be limited to the number of channels it is equipped to support.

In all digital cordless telephone formats, the radio spectrum is divided into a number of discrete RF channels using Frequency Division Multiple Access (FDMA) Techniques. Additionally, some systems such as CT-3 employ Time Division Multiple Access (TDMA) to multiplex several traffic channels into each RF channel. In all cases, traffic channels are processed individually at the base station before interconnection to the PSTN occurs. Traffic

channels may be used to transport coded voice or data.

In general, each radio base station consists of a number of RF modulators and demodulators for radio communications with the handsets, multiplexers and demultiplexers for handling the transmission of digital information over the radio link, encoders and decoders for converting the voice messages into digitally-coded streams of data, and a control system for error correction, establishment of radio links, synchronization, and other functions related to digital radio transmission.

The PSTN interface to each radio base station requires sufficient capacity, using existing twisted copper pairs or new fiber based terminal equipment. Each channel of each base station represents a new telephone line which must be established to the PSTN switch network. In many cases, new transmission equipment is needed to serve the radio base stations.

Thus a major problem, common to both conventional cellular and PCS radiotelephony systems, is their requirement for numerous spatially distributed base stations in order to provide coverage over a substantial area. The low power and limited range of PCS base stations makes this problem more acute in the case of PCN networks, particularly if any substantial degree of user mobility is to be provided. This problem has two facets, the first being the cost and complexity of the base stations themselves, and the second the cost and complexity of the distribution network required to pass signals to and from the base stations.

It is known in the case of cellular radio systems to utilize fibre optic trunks associated with a CATV system

to provide signal distribution to the base stations of a cellular system, as described in an article "Rogers Fiber Architecture" by George Hart and Nick Hamilton-Piercy, CED Magazine, July 1989. Various other proposals have also been made for the provision of telephony services making use of the existing fixed plant of CATV systems, particularly those having two way capability. An article "Cellular Radio and Cable TV = Cellular Cable" also points out the capability of existing two-way CATV systems, particularly those using optical fiber technology, to replace conventional twisted pair plant in the transmission of telephone communications, the suggestion (no details are provided) being that a CATV system might in effect replace the transmitter of a cellular base station, with the signal being distributed by cable instead of broadcast, analogously to the distribution rather than broadcast of television and radio signals by the system, but making use of its two-way capability. A system operating generally on these principles is disclosed in U.S. Patent No. 4,757,496 (Bartholet), which discloses frequency-agile stations connected to a coaxial cable network in a manner such as to replace conventional twisted-pair local distribution of telephone signals. U.S. Patent No. 4,644,526 (Wu) discloses a device for connection of station to a network, which may be implemented by coaxial cable, by translating between a single frequency division duplex signal and separate signals carried on different sidebands of a common carrier.

The architecture and technology of typical CATV systems is described further in "Cable Television System Overview-1987", published September 14, 1987 by American Television & Communications Corporation, Englewood, Colorado. Further discussion of two-way CATV systems is to be found in Chapter 12 of the book 'Cable Television', 2nd edition, by

John E. Cunningham, published 1980 by Howard W. Sams.

We have now found that we can effectively exploit the capabilities of a two-way CATV system in PCS and analogous radiotelephony systems by utilizing the CATV system to provide a base station or stations with a distributed radio transmission capability, thus enabling each base station to service a far larger area than would otherwise be possible.

In its broadest aspect, the present invention provides a radiotelephony interface in which the area coverage of base station equipment is increased by connecting it to a plurality of antenna drivers by frequency division duplex transmission of transmitted and received signals between the base station equipment and the antenna drivers over a bidirectional cable television system, in frequency bands reserved in that system for downstream and upstream communications respectively.

According to a further aspect of the invention, there is provided a radiotelephony interface for use in a multi-channel radio telephony system to establish wireless communication between multiple portable transceiver units and a telephone network, comprising at least a part of a CATV system including a headend or hub and a plurality of drops in two-way communication with the headend or hub, at least one means at the headend or hub for processing signals received from and for transmission in multiple channels to portable radio transceivers, utilizing blocks of channels occupying defined portions of the frequency spectrum for transmission and reception, and a plurality of remote antenna drivers connected to individual drops of the CATV system, the remote antenna drivers each comprising an antenna, first frequency conversion means for block

converting signals, received from said transceivers by said antenna in said defined portion of the frequency spectrum, to a portion of the frequency spectrum allocated in the CATV system for upstream communications, means for applying said converted signals to the associated drop as upstream signals, second frequency conversion means for block converting downstream signals, received from said drop for transmission in a portion of the frequency spectrum allocated in the CATV system for downstream communications, to the portion of the frequency spectrum defined for transmission of such signals to said transceivers, and means for applying said block converted downstream signals to the antenna, and the signal processing means at the headend or hub comprising means for transmitting signals to the drops in a block of channels within said portion of the frequency spectrum allocated in the CATV system for downstream communications, and means for receiving signals from the drops in a block of channels within said portion of the frequency spectrum allocated in the CATV system for upstream communications.

The invention also extends to a remote antenna driver having the features set forth above.

The difficulties associated with the construction of a PCN may be significantly reduced by the use of the invention. The bidirectional transport of signals on two-way coaxial cable CATV facilities is well documented in the prior art. Conventionally, the conveyance of radio frequency (RF) signals is at frequencies greater than 50 MHz from an originating location (headend) or relay points (hub) downstream to residences and businesses; upstream conveyance is at frequencies in the range 5 to 30 MHz from residences and businesses to the hub or headend. The signals are conveyed to and from homes and businesses via

single coaxial cable drops which are connected to a coaxial cable feeder line by way of signal couplers. The feeder line may be in turn connected to a coaxial trunk line or to opto-electronic transducers which are connected via optical fiber to a hub or headend.

By utilizing a CATV system to distribute the signals of a base station or group of base stations at the hub or headend to multiple antennas, the coverage of such stations can be greatly increased. If, as will usually be the case, multiple base stations are required to handle traffic demands, these may be co-sited at the hub or headend, except again for their shared distribution and remote antenna drivers. A remote handset exchanges RF signals with the CATV facility via a remote antenna driver (RAD). The number of handsets accessing the CATV facility at each RAD is only limited by the base station capacity at the hub or headend serving that RAD. The RADs plus the CATV facility are in effect a low loss transmission path between portable handsets and the main portion of the radio base stations at the hub or headend which allows a much greater distance between the handset and that main portion than would otherwise be possible. Calls are handled according to techniques already well known in cellular telephone networks, or as set forth in the publications set forth above.

A multiplicity of RADs may be connected to the CATV facility throughout a community, with widely scattered portable handsets able to communicate with the public switched telephone network (PSTN) through base station equipment located remotely from the RADs at a common hub or headend of the CATV system. The equipment required at the headend or hub may be provided by means of appropriate circuit modifications of a conventional radiotelephony base

station, to provide reception and transmission in appropriate frequency bands for interfacing with the CATV system, or an intermediate unit may be connected to radio base station antenna ports, the unit operating in a complementary manner to a RAD to provide the necessary frequency conversion and matching. The equipment must provide for the propagation delays inherent in a CATV system. A multiplicity of voice circuits interconnect the multiplicity of radio base stations to the PSTN in conventional manner.

In general, the RF frequencies allocated for PCS cannot be conveyed on CATV facilities and so the principal function of a RAD is to translate the PCS frequencies to frequencies suitable for CATV. Hence signals intended to be delivered to a portable handset by the radio interface of the invention are typically conveyed in a frequency band above 50 MHz on the CATV facility, and translated by a RAD in the vicinity of the portable handset to a frequency in the receiver frequency band of the portable handset. Signals transmitted by the portable handset are received by the RAD and translated to a frequency typically in the range 5 to 30 MHz for conveyance by the CATV system to the headend radio base station equipment serving that portable handset.

The range of frequencies which each RAD can accommodate is desirably sufficient to allow all channels available for PCS to be used without restriction. All RADs use functionally compatible translation systems to ensure any portable handset within communications range of any RAD can communicate with any free base station on any free channel, as established by the normal operation of the PCS system equipment as if the portable handset was in the vicinity of a conventional base station.

A presently preferred exemplary embodiment of the invention is described further below with reference to the accompanying drawings, in which:

Figure 1 is a schematic diagram showing part of a CATV system equipped to provide an interface according to the present invention;

Figure 2 is a more detailed schematic diagram of a remoted antenna driver incorporating the system of Figure 1; and

Figure 3 is a schematic diagram showing an interface to a PSTN incorporated in a hub of the CATV system of Figure 1.

Figure 4 is a schematic diagram of part of a base station receiver illustrating means compensating for propagation delays in the CATV system.

Figure 1 shows a segment of a CATV facility including a hub 60 connected to a headend via a supertrunk 61 as well as to the PSTN via voice circuits 62. Coaxial cable trunks 63 with bridger amplifiers 64 convey signals between the hub 60 and coaxial distribution feeders 65. Line extenders 66 amplify the signals to compensate for signal attenuation caused by cable and by couplers contained within multitaps 67. Coaxial drop cables 68 (of which only one is shown) provide cable television service to residences and businesses where television sets 69 are the usual terminal equipment. A remote antenna driver (RAD) 70 is connected to the drop 68 to allow portable telephone handsets 71 in the vicinity of the drop to communicate with the remaining equipment of a radio base station or stations contained in

the hub 60. This equipment will be referred to as the base station(s) although it should be understood that the entire system to be described, including the CATV system and RADs, together constitutes a form of distributed radio base station which acts collectively as the interface between the PSTN and the handsets 71. A multiplicity of RADs 70 may be connected to a multiplicity of drops 68 and multitaps 67 on a multiplicity of feeder lines 65 and line extenders 66 which in turn connect to a multiplicity of bridger amplifiers 64 on a multiplicity of trunks 63 connected to a common hub 60. Each bridger amplifier 64 is equipped with amplifiers and diplexing filters to support two-way operation in a manner conventional in the art of two-way CATV systems. Similarly each line extender 66 is equipped for two-way operation such that signals in the range of frequencies 5 to 30 MHz may pass with approximately 30dB attenuation from the RAD 70 to the hub 60. Signals above 50 MHz, up to the design limit of the amplifiers 64, line extenders 66 and multitaps 67, which limit is typically 400 to 550 MHz, are conveyed with approximately 50 dB attenuation from the hub 60 to RAD 70. These attenuation figures are exemplary only and may vary significantly with respect to individual drops 68.

Although Figure 1 shows connections being established to the PSTN through equipment located at the hub 60, such connections could also be established through similar equipment located at the headend, particularly in the case of a relatively smaller CATV system. Moreover, the coaxial trunk cables connecting bridging amplifiers 64 to the hub 60 may be replaced by optical fibers with appropriate transducers to support two-way signal conveyance in accordance with normal CATV system practice, without affecting the practicality or operation of the invention.

Referring now to Figure 2, the RAD 70 will be described in more detail. The drop cable 68 is connected to a diplexing filter 1 by means of which frequencies in the range 5 to 30 MHz present on a conductor 2 may be inserted onto the drop cable 68 with minimum attenuation. Signals above 50 MHz pass through the diplexing filter from the drop cable 68 to a conductor 3 from which they are available to a forward frequency translation subsystem 7 via a coupler 4 and a conductor 5. A low attenuation path through coupler 4 is made available via conductor 6 to a suitable connector on the RAD 70 for connection of a television 69, for the purpose of receiving television programming normally available on the CATV facility. The RAD 70 has no effect on normal CATV service other than a small attenuation of signals above 50 MHz.

PCS signals from the radio base station equipment in the hub and intended for a portable handset 71, are passed to the forward frequency translation subsystem 7. This acts to change low power signals from conductor 5, in any one of a block of channels in a pre-determined band of frequencies typically having a bandwidth equal to that allocated for PCS channels, but located between 50 and 550 MHz, into relatively higher power signals for transmission in the frequency band allocated for PCS channels receivable by the handset 71, typically in the range 900-1000 MHz. The transmission signals are delivered to an antenna 26 via an electronic switch 25. The band of frequencies to be so changed will typically be from 4 to 20 MHz wide, as determined by the portion of the RF spectrum allotted to the PCS. All RADs 70 will perform an identical translation of the complete PCS band of frequencies.

Within the subsystem 7, the low level downstream PCS signals from conductor 5 are amplified by a preamplifier

11 with fixed gain and connected via a coupler 12 to a mixer 13. A local oscillator 14 drives the mixer 13 at a suitable frequency in known manner to cause the PCS signals to be heterodyned to an intermediate frequency, typically in the vicinity of 45 MHz, and further amplified by a variable gain narrow band amplifier 15 whose output is connected to a band pass filter 18 via a coupler 17. The intermediate frequency, band limited, PCS signals are heterodyned a second time by a mixer 19 which is driven by a local oscillator 20 so as to be translated to the desired transmission frequency band. Band pass filter 21 prevents spurious mixer signals from reaching a power amplifier 22, which delivers the maximum allowable PCS signal power to the antenna 26 via a coupler 23 and the electronic switch 25. A sample of the power amplifier 22 output is diverted by the coupler 23 to a broadband detector 24 to provide an automatic level control signal which limits the gain of the power amplifier and so prevents excessive output power which might otherwise result in signal distortion and unlawful emissions.

A sample of the input signal is diverted by the coupler 12 to a filter 27 which extracts control and frequency reference signals, which signals are subsequently amplified by an amplifier 28 and demodulated by a demodulator 30 to provide control information to a controller 37 via conductor 31. A frequency reference is provided to the controller via coupler 29 to ensure that the various local oscillators in this and other RADs, which are frequency synthesizers, are operating coherently at predetermined frequencies.

The coupler 17 is used to divert a sample of the RF power at the output of the variable gain intermediate frequency (IF) amplifier 15. A power detector 32 delivers

a signal to the controller 37 used for controlling the gain of the amplifier 15 by a signal output on a conductor 34. The signal amplitudes in this subsystem also provide an indication of the input signal level to the RAD and thus the net RF path attenuation between the hub 60 and the RAD 70. The estimated path loss is used to provide a signal on conductor 54 which controls the gain of an amplifier 53 for optimum launching of PCS signals received from the portable handset 71 onto the CATV facility for conveyance to the hub 60. A frequency conversion subsystem 8 transforms low power emissions received by the antenna 26 from portable handsets 71 on channels allocated in the PCS frequency spectrum into higher power replicas displaced in frequency so as to be compatible with the upstream transport capabilities of conventional bidirectional CATV facilities, specifically an allotted band within the 5 to 30 MHz frequency band wide enough to accommodate the allocated block of reception channels.

The subsystem 8 is connected to the antenna 26 through the switch 25 by conductor 39, which passes signals through as an input filter 40 to a fixed gain amplifier 41 with conventional squelch capabilities. Provided the received PCS signals are of sufficient level to give reliable communication, the squelch of the input preamplifier 41 will be removed and the signals will be delivered to a mixer 43 which is driven by a local oscillator 44. The filter 40 ensures that unwanted signals outside the PCS frequency band are attenuated sufficiently to prevent interference likely to disrupt reliable communications. The output of the mixer 43 is at an intermediate frequency, typically 45 MHz, and is amplified by a band-limited variable gain amplifier 46 and delivered to a mixer 49 via a coupler 48. A local oscillator 51 drives the mixer 49 such that its output contains the PCS signals translated

to the desired band within the range of frequencies 5 to 30 MHz. A filter 50 prevents undesired mixer products from passing to the output amplifier 53. The coupler 48 diverts a sample of the PCS signal to an automatic gain control module 47 in order to provide optimum gain of the amplifier 46 relative to the PCS signal level received at antenna 26, which may vary over a very large range. More specifically the amplifier 46 operates at maximum gain for the lowest received signal power, its gain decreasing linearly with increasing received signal power until minimum gain is reached, whereafter it maintains minimum gain as receiver input power increases further.

The electronic switch 25 is controlled by the controller 37 such that it is synchronized with signal packets being exchanged between the RAD 70 and the portable handset 71. Suitable control information, extracted from the downstream signals, is delivered to the controller 37 via the demodulator 30 on conductor 31 to ensure that synchronization is achieved. Because of limitations on the isolation achievable in practical switches between the conductors 38 and 39, the amplifiers 22 and 41 are controlled by signals on conductors 36 and 42 so as to turn the amplifiers off when not connected to the antenna 26.

The RAD may be contained in an aesthetically pleasing container suitable for installation in homes or offices and is typically powered by commercial 120V AC via a wall mount power supply that delivers low voltage AC power to it. A low voltage power supply 9 uses this low voltage AC input to generate the direct current voltages necessary to power the RAD. A battery 10 is used to power the RAD during interruption of the commercial power source. Outdoor versions of the RAD may be powered by 60V square wave power conventionally available on the coaxial feeder cable 65,

the power supply being adapted in known manner to utilize this supply. As a further alternative, the RAD may be housed within a cable television converter unit, and share the power supply of that unit. This alternative has the advantage that it is more likely to provide a favourable location for the RAD antenna.

Most functions of the RAD described so far are substantially independent of the implementation of the PCS, since they are limited to block frequency conversion, power amplification and matching to the RAD antenna and to the CATV drop.

Several proposed radio Common Air Interfaces (CAI) for PCS radio communication employ Time Division Duplex (TDD) operation. As a result, the RAD must be designed for TDD operation on the radio side. A CATV plant will not support TDD operation, however, as it is frequency-divided into two bands: a high band which handles downstream transmission (head-end to hub to subscriber) and a low band which handles upstream transmission (subscriber to hub to headend).

To accommodate a CATV transport system from the remainder of the base station equipment, the latter is designed to provide Frequency Division Duplex (FDD) output. The duplex channels are divided into "transmit" and "receive" links which are transported on the CATV downstream and upstream bands, respectively.

As an example of bandwidth requirements, assume a PCS system using CT-2 plus. Such a system would occupy 8 MHz of bandwidth, with a nominal 80 channels spaced at 100 KHz between channels. In the simplest case, the transmit link would be carried downstream in an 8 MHz allocation (eg.500-

508 MHz) and the receive link would be carried upstream in an 8 MHz allocation (eg. 22-30 MHz). A conventional diplexing filter is used to couple the base station equipment to the CATV plant.

Conversion of FDD to TDD is performed in the RAD by the switch 25 under control of the controller 37 which performs the necessary time duplexing. An FDD radio link between the RAD and the handheld units can however also be accommodated by appropriate control or elimination of the switch. For the purposes of description, TDD operation of the link is assumed. The controller would regenerate the synchronization signals SYNC and SYNC on lines 36 and 42 from the downstream signal sample received from demodulator 30.

In a conventional PCS system, the handset communicates directly with the base station via a radio frequency link. The only time delay in the path is due to radio propagation delays between the base station and the handset. Due to the short radio range of these systems (typically less than 300 m for reliable radio coverage) these propagation delays are short. As a result, the digital transmission schemes developed for such systems do not incorporate elaborate equalization to compensate for time delays, and FDD operation is practicable without such equalization. The incorporation of CATV plant into the base station-to-handset transmission path does however introduce substantial time delays.

In a conventional PCN base station, the transmitter and receiver sections are synchronously coupled. A clock switches the transceiver between transmit and receive modes. The time frame employed depends on the Common Air Interface CT-2 and CT-2 Plus employ a 2 ms time frame (Tx

1 ms, Rx 1 ms) while CT-3 employs a 16 ms time frame (Tx 8ms, Rx 8 ms). This mode of operation requires that the base-to-handset data burst be closely followed by the handset-to-base data burst. A lengthy delay may cause the first few bits of a transmission to be lost resulting in no communications being established between base station and handset.

A CATV compatible PCS base station requires that the transmitter and receiver sections be asynchronous, i.e. the receiver must be allowed to 'slip' in time relative to the transmitter, so that received packets can be processed when received outside a time slot allocated for reception, and then delayed further so as to fall into such a time slot. Each transceiver within a multi-transceiver base station must employ an independent slip timing buffer so as to compensate for varying propagation delays in a system employing a multiplicity of distributed RADs. This is described further below with reference to Figure 4.

The handsets do not suffer from CATV induced delay because they are configured to slave their transmission to the data bursts or packets which they receive from the base station. The TDD to FDD translation at the RAD is also slaved to the data bursts received by the handset and since it occurs in close physical proximity to the handset, no propagation delays between the handset 71 and the RAD 70 are large enough to cause a problem. In other words neither the RAD nor the handsets need to make any provision for propagation delays within the CATV system since it is the responsibility of the base station equipment at the hub (or headend) to make such provision based on the timing of the upstream packets it receives from the RAD.

When the CAI between the RAD and the handset operates

in TDD mode and the proposed CATV transport system (Base Station-to-RAD) operates in an FDD mode, the CATV bandwidth is under-utilized because the transmit bandwidth is active only half the time and the receive bandwidth is active only half the time.

In order to utilize more fully the CATV transport capacity, a technique referred to as "Even/Odd" channel assignment can be utilized to increase the loading of the CATV plant and thus increase efficiency.

To take an example, each CT-2 Plus channel occupies a bandwidth of approximately 200 KHz. Therefore in an 8 MHz allocation, 40 channels may be transmitted simultaneously without adjacent channel interference. These 40 channels (the "even" channels) would be active during the transmit cycles of a first group of RADs designated "even". Also connected to the same CATV plant would be an approximately equal number of "odd" RADs, which would be in the receive mode while the even RADs are in the transmit mode. A total of 40 channels can thus be received simultaneously without adjacent channel interference. At any given time, therefore, there are up to 40 channels in the transmit mode and up to 40 channels in the receive mode for a total of 80 active channels in an 8 MHz allocation.

During a first phase of the synchronization signal used to operate the switch 25 in the RADs, the odd RADs would be transmitting on up to 40 channels and the even RADs would be receiving on the even channels, whilst during a second phase, the operation would be reversed. The only difference between 'odd' and 'even' RADs is the relative phase of the signals SYNC and $\overline{\text{SYNC}}$, which can be controlled by a signal from the equipment at the hub or headend. The RADs can be dynamically or manually assigned to operate in

one of the two phases by a signal from the hub or headend equipment.

A CATV system used for PCS systems must allow for the assignment of a block of channels in a contiguous frequency band to the service. If the radio CAI interface employs a 4 MHz spectrum allocation then an exclusive and contiguous 4 MHz of CATV spectrum must be assigned in each of the downstream and upstream paths. If this is not the case then the design of the RAD becomes prohibitively complex. Similarly, if the radio CAI is assigned an 8 MHz allocation, and the CATV transport is designed to handle the entire allocation, then an exclusive and contiguous 8 MHz of CATV spectrum is required in each of the downstream and upstream paths.

Except for this requirement, however, the actual frequency assigned is not restricted to any particular part of the CATV frequency spectrum. The actual assignment is determined by the CATV plant operator and is a function of the capabilities of the plant. An essential requirement, of course, is that the plant be capable of bi-directional operation.

The actual spectrum allocations are a function of traffic requirements, CATV system architecture, and utilization of the spectrum for applications other than PCS. If necessary, several blocks of spectrum can be assigned to the service to increase capacity. Different versions of the RAD would then be employed in the system to translate the CATV spectrum blocks into the radio common air spectrum.

Frequency re-use is a function of CATV system architecture. If a block of frequencies is employed at the

headend of a distribution system, then that block may not be re-used again in that system. On the other hand, if the block of frequencies is used at a hub, then the block of frequencies may be re-used at other hubs, in a technique analogous to a technique known as "cell-splitting" in the cellular telephone industry, used to increase frequency re-use as the density of cellular subscribers increases over time.

Pilot signals may be used for various functions in the proposed system. A downstream pilot signal may be used for base station-to-RAD signalling, and an upstream pilot signal may be used for RAD-to-base station signalling. The pilot signals may be located in the PCS transport band or an out-of-band allocation may be used. A number of modulation techniques are also possible. The actual allocation and modulation technique can be determined by the CATV operator to suit system requirements. At the least, a downstream pilot is desirable as a simple means to provide the synchronization signal for TDD switching, and a frequency reference for the frequency translators employed in the RAD.

The downstream pilot may also be modulated with data at the base station to control various functions at the RAD. These possible functions include:

a) "Even/Odd" channel block assignments
b) Spectrum block assignment
c) Output power control (RAD-handset interface)
d) Remote enable/disable of RADs
e) Input level control (RAD-CATV interface)
f) Output level control (RAD-CATV interface).

An upstream pilot generated by each RAD can provide functions such as acknowledgement of control messages and

power failure or device failure reporting.

In addition to these PCS-related functions, the two pilots can also be used for various other purposes. More specifically, they can carry data related to auxiliary services already proposed or implemented in two-way CATV systems such as special functions related to the CATV operation e.g. Pay TV, Pay-per-view TV and remote decoder enable/disable, and telemetry control of household utility services such as electricity and natural gas.

Referring now to Figure 3, there is shown exemplary base station equipment 100 provided at the hub 60 (or headend) for connection to multiple twisted pair circuits 102 forming the connection 62 to a PSTN 104. The base station equipment provides input and output signal lines 106 and 108 which are connected to the conventional CATV plant 110 at the hub (or headend) in which the signals are inserted into or extracted from the cables 63 extending out of the hub using conventional techniques. In the particular example being discussed, the downstream signals on line 108 are in a selected available frequency band, of a width corresponding to the band width allotted to the PCS service being implemented, somewhere within the 50-550 MHz frequency band allocated for downstream signals. The upstream signals are in a selected available frequency band in the 5 - 33 MHz frequency band allocated for upstream signals. It will be understood of course that, whilst these upstream and downstream allocations are typical of modern CATV installations, they may be varied in which case the frequencies utilized for upstream and downstream PCS signals will be selected accordingly.

If the signals on lines 106 and 108 are to be provided and processed using conventional base station equipment

intended for processing signals for direct transmission to and reception from PCS transceivers, then these signals must be translated to and from the frequencies utilized by the PCS air interface. In such a case, the upstream signals on line 106 are applied, together with a local oscillator signal from a phase locked loop synthesizer 112 to a mixer 114 to generate signals in the PCS air interface band. The channel frequencies so generated will be the same as those utilized for communication between the transceivers 71 and the RADs 70. Likewise, the base station signals to be transmitted on line 108 are translated, by a further mixer 116 receiving a local oscillator signal from the synthesizer 112, to the frequencies utilized for communication between the RADs 70 and the transceivers 71. The downstream signals are amplified by a bandpass amplifier 118 before application to the line 108, the pass band of the amplifier corresponding to the downstream CATV allocation for the signals, and the upstream signals are amplified by a bandpass amplifier 120 having a pass band corresponding to that of the base station receiver equipment. If the base station equipment is adapted to handle the allocated CATV frequencies directly, it will be understood that the mixers 114 and 116, and the synthesizer 112, may be omitted.

The upstream signals from the amplifier 120 are applied to a splitter 122, which forwards the signal to multicouplers 124 serving two groups 126 and 128 of receiver cards each providing an interface to a PSTN circuit 102. According to the nature of the PSTN circuit, the signals output by the cards may be analog signals or include an interface to provide pulse code modulated signals such as a standard T1 interface. The T1 interface may be an intelligent interface including a multiplexer with a packet assembler/disassembler (PAD) 130 for routing

data or facsimile signals to a data network 132.

Signals from a PSTN circuit 102 pass to a transmitter card in one of two groups 134 and 136, which cards may be interfaced to that circuit as described above in relation to the receiver cards. Outputs from the transmitter cards are passed to combiners 138 and thence to an RF switch 140 which selected the outputs of either group 134 or group 136 according to the phase of a synchronizing signal SYNC or $\overline{\text{SYNC}}$ received from a pilot signal generator 142. A pilot signal generated by the generator 142 and modulated with this synchronizing signal is also combined with the transmitter output by a combiner 144 to perform the functions of the downstream pilot signal already discussed above. If an out-of-band pilot signal is to be used, and the mixer 116 is utilized, a somewhat different arrangement is needed so that the pilot signal carrier is not modified by the mixer 116. In this case the synchronizing signal and other data to be carried by the pilot is supplied to a frequency modulator 146 together with a carrier frequency generated by the synthesizer 112, and the pilot signal is combined with the transmitter signals by a combiner 148 downstream of the mixer 116. The pilot generator 142 and the synthesizer 112 receive a common reference frequency from an internal frequency reference 148, or an external reference 150 if frequency coherence with other base stations is needed.

Upstream pilot signals, already discussed above, may be recovered if utilized from the received signal on a line 152, and applied through a demodulator 154 to a microcontroller 156, equipped with a terminal 158, which supervises the transmission and reception of data carried by the pilot signal and supplies data to be transmitted to the pilot generator.

The receiver and transmitter cards operate generally as is conventional in the cellular telephony and PCS art, with each card being capable of receiving or transmitting a signal on any channel of the block of channels comprised by the PCS band, and the control functions required for allocating channels and generally supervising communications are also conventional in this art. Since they form no part of the present invention they have not been described nor illustrated in detail. As however has been previously mentioned and will be described further below, provision must be made in the receiver cards to allow for the substantially larger and variable propagation delays which will occur in a CATV network as compared with conventional short range radio communication between base stations and portable or mobile transceivers.

In the example described, the base station equipment is grouped in such a way to allow 40 channels in the CT-2 Plus format to be combined together during the transmit phase of the Time Division Duplex (TDD). Although the nominal RF channel spacing in CT-2 and CT-2 Plus is 100 KHz, the actual bandwidth consumed by the modulation of this channel is actually 200 KHz. In formats such as CT-2 or CT-3, the number of channels would be adjusted accordingly (20 channels for CT-2).

To obtain the maximum number of channels over the plant it is necessary to synchronize all of the transmit portions of the CT-2 equipment, using the synchronization signals SYNC and $\overline{\text{SYNC}}$ on lines from the pilot generator 142. This prevents spill overs or dispersion effects on what would appear to be adjacent channels. This bandwidth requirement reduces the total number of available channels to half under worst case conditions. The CATV plant however

provides a bi-directional frequency duplex trunk system. When the TDD CT-2 system is mapped into the CATV plant system using frequency translation techniques it is found that during the receive portion of the TDD cycle the RF energy in the CATV plant is zero for the block of frequencies being utilized. This means that this block is available for use, and the odd/even interleaving technique outlined above can be implemented.

In describing Figure 3, it has already been noted that duplicate sets of receiver cards 126, 128 and transmitter cards 134 and 136 are provided. Each first set of cards is provided with the synchronization signal SYNC on line 160 and each second set of cards with the synchronization signal SYNC of reverse phase on line 162, such that only the first sets or the second sets are strobed to output receive or transmit signals at any one time. The operation of the switch 140 is also controlled by the pilot generator 142 so that only the active set of transmitter cards is connected to the CATV network at any one time.

A similar switching technique cannot be used in respect of the receiver cards since the propagation delays suffered by the received signals in different channels will be different according to the origin of the signal. Individual adjustment is therefore necessary at each receiver card, and one technique for achieving this is shown in Figure 4.

Referring to Figure 4, showing schematically a portion of one of the receiver cards in sets 126 and 128, a signal from one of the multicouplers 124 is applied to a frequency shift keying (FSK) receiver 200 to recover data from received data packets. In a typical CT-2 or CT-2 Plus PCS, signal packets are transferred in TDD to and from the

transceivers in alternate 1 ms intervals to provide a 2 ms cycle with transmit packets Tx from base station to transceiver and receive packets Rx from transceiver to base station following each other in immediate succeeding time slots at the transceiver, as shown at the top of Figure 4.

As a result of propagation delays in both downstream and upstream passage through the CATV system, there is likely to be a significant and highly variable delay between the end of the period allowed for transmission of a Tx packet at the base station, and the reception of the corresponding Rx packet. These delays will frequently be such that the Rx packet will not be received within the time slot allowed by the TDD synchronization signal SYNC or $\overline{\text{SYNC}}$ for its reception, resulting in loss of part of the Rx packet, as illustrated at the top of Figure 4.

To overcome this problem, provision is made to apply an additional delay to the Rx packets in the receiver so that each is delayed by a full TDD cycle period, in this case 2 ms, or a multiple of that period, so as to ensure that they are received in the proper phase relationship with the transmission of the associated Tx packets. The data recovered by receiver 200 is applied to a clock recovery circuit 202, which recovers from the data a data bit rate clock signal and a strobe signal marking the beginning and end of each packet. The clock signal is used to clock data from the receiver 200 into a first-in, first-out (FIFO) register 204, when enabled by the recovered strobe signal, as illustrated by the adjacent timing diagram. Data can be clocked out of the FIFO 204 on a line 206 by a base station system clock signal 208 when the receiver is enabled by the signal SYNC or $\overline{\text{SYNC}}$, as the case may be, provided that a FIFO status line 210 indicates that the FIFO contains a complete Rx packet, i.e. the strobe

signal is not active and the FIFO contains data. The received data packet can then be decoded and either converted to an analog signal, re-encoded as a PCM signal having an appropriate bit rate, or passed to a PAD 130 for further processing.

Whilst the foregoing description has related to an exemplary embodiment of the invention relating to a PCS, it should be appreciated that the invention could also advantageously be employed in a cellular radiotelephone system with suitable changes of parameters, and indeed in any application where the provision of wide area base station coverage is desired in a multi-channel radiotelephony system. Whilst the transceivers in the system described have commonly been referred to as handsets, it should be understood that the transceivers may be any of several forms, whether handheld, mobile, or even fixed where a conventional wired telephone circuit cannot conveniently be provided. Whilst an arrangement in which the CAI to the handsets uses a TDD format, the invention is also applicable to FDD formats, apart from those features specifically predicated upon the use of TDD. The nature of the telephone network to which the invention interfaces is significant only to the extent that the receivers and transmitters of the base station equipment must be provided with a suitable interface to the network.

CLAIMS:

1. A radiotelephony interface in which the area coverage of base station equipment is increased by connecting it to a plurality of antenna drivers by frequency division duplex transmission of transmitted and received signals between the base station equipment and the antenna drivers over a bidirectional cable television system, in frequency bands reserved in that system for downstream and upstream communications respectively.

2. An interface according to claim 1, wherein the radiotelephony system utilizes an air interface employing time division duplexing, and the antenna drivers perform conversions between frequency division multiplex and time division multiplex.

3. An interface according to claim 2, wherein the base station equipment comprises duplicated sets of transmitters and receivers, with each set of transmitters operating in successive frequency division multiplex time slots of the air interface whilst the other set of transmitters is inactive, and each receiver incorporating means to delay signals received from the air interface sufficiently to locate them in reception timeslots between the transmission timeslots of their associated transmitter.

4. A radiotelephony interface for use in a multi-channel radio telephony system to establish wireless communication between multiple portable transceiver units and a telephone network, comprising at least a part of a CATV system including a headend or hub and a plurality of drops in two-way communication with the headend or hub, at least one means at the headend or hub for processing

signals received from and for transmission in multiple channels to portable radiotelephone transceivers, utilizing blocks of channels occupying defined portions of the frequency spectrum for transmission and reception, and a plurality of remote antenna drivers connected to individual drops of the CATV system, the remote antenna drivers each comprising an antenna, first frequency conversion means for block converting signals received from said transceivers by said antenna in said defined portion of the frequency spectrum, to a portion of the frequency spectrum allocated in the CATV system for upstream communications, means for applying said converted signals to the associated drop as upstream signals, second frequency conversion means for block converting downstream signals received from said drop for transmission in a portion of the frequency spectrum allocated in the CATV system for downstream communications, to the portion of the frequency spectrum defined for transmission of such signals to said transceivers, and means for applying said block converted downstream signals to the antenna, and the signal processing means at the headend or hub comprising means for transmitting signals to the drops in a block of channels within said portion of the frequency spectrum allotted in the CATV system for downstream communications, and means for receiving signals from the drops in a block of channels within said portion of the frequency spectrum allocated in the CATV system for upstream communication.

5. A remote antenna driver for establishing a radiotelephony link between a CATV system and portable radiotelephone transceivers on any of a plurality of channels within a defined allocation of the radio frequency spectrum, comprising an antenna, first frequency conversion means for block converting signals received from a transceiver by said antenna in said allocation of the

frequency spectrum, to a portion of the frequency spectrum allocated in the CATV system for upstream communications, means for applying said converted signals to a drop of the CATV system as upstream signals, second frequency conversion means for block converting downstream signals, received from said drop for transmission in a portion of the frequency spectrum allocated in the CATV system for downstream communications, to the allocation of the frequency spectrum defined for transmission of such signals to said transceivers, and means for applying said block converted downstream signals to the antenna.

6. A radiotelephony interface substantially as hereinbefore described with reference to the accompanying drawings.

7. A remote antenna driver substantially as hereinbefore described with reference to Figure 2 of the accompanying drawings.

8. A radiotelephony interface, having 'odd-even' channel interleaving substantially as hereinbefore described with reference to the accompanying drawings.

9. A radiotelephony interface incorporating a cable based frequency division multiplex signal distribution system from base station equipment to remote antenna drivers which provide a time division multiplex air interface, the signal distribution system being substantially as hereinbefore described with reference to the accompanying drawings.